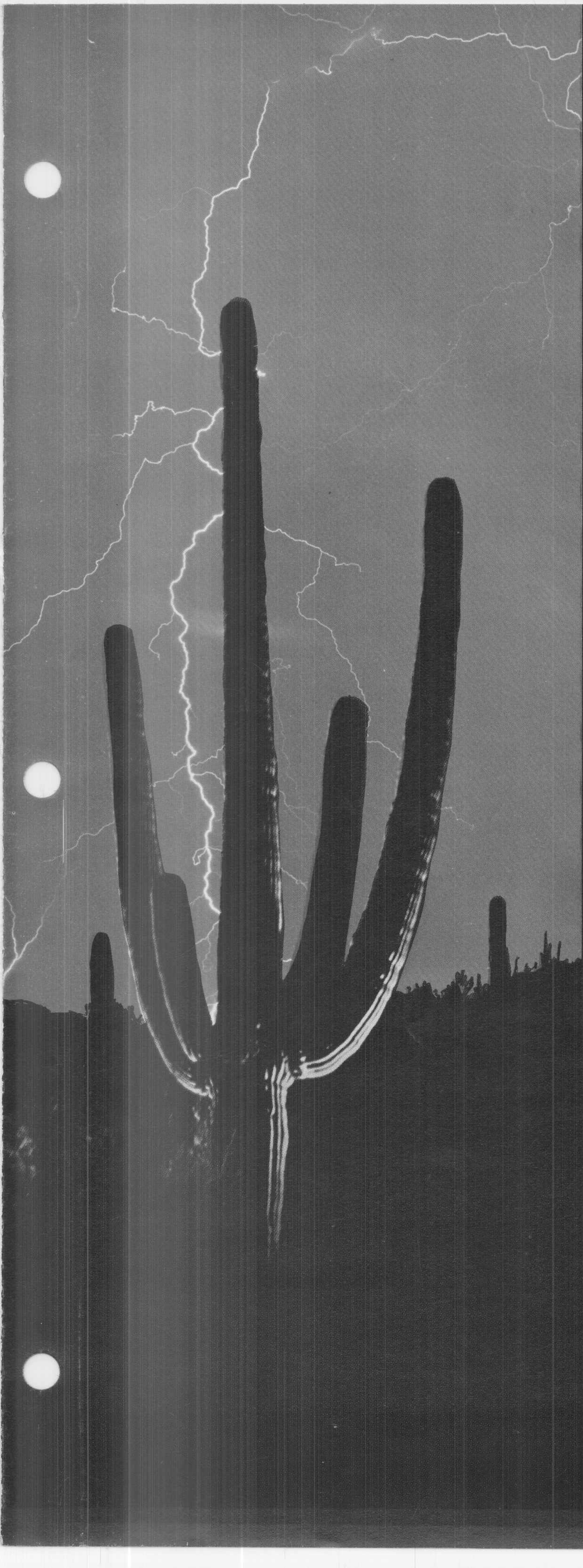


TransZorb®

QUICK REFERENCE GUIDE

PROVIDING PROTECTION FOR

- Telecommunications
- Military
- Computer
- Industrial
- Test & Instrumentation
- Medical
- Automotive

GENERAL SEMICONDUCTOR INDUSTRIES, INC.

A TransZorb® is a class of diode, two terminal, that is designed to provide transient over voltage protection in electrical circuits. It is an avalanche, P-N junction, surge suppressor that can operate in either of the forward or reverse direction of its V-I characteristics curve. If the volt amp characteristics are non-symmetrical, then the characteristics values must be specified with each polarity or direction. All of the electrical characteristics are specified at 25°C ambient temperature unless otherwise indicated.

The TransZorb is applied as a shunt or across the line (DC or AC) component to provide protection within the limits of the *Standoff Voltage* (V_R), and the *Maximum Clamping Voltage* (V_C). It will exhibit a relatively high impedance at a normal system voltage (equal to V_R) before and after the surge. The suppressor will limit surge voltage on the equipment by providing a low impedance shunt to conduct a surge discharge current (I_P). TransZorbs are specified according to their DC or peak ratings and electrical characteristics.

There are four key specific parameters which must be considered in the selection of a TransZorb. These include: Reverse Standoff Voltage (V_R), Peak Pulse Power (P_p), Peak Pulse Current (I_{pp}), and Clamping Voltage (V_C). A TransZorb® is normally selected according to the **Reverse Standoff Voltage** (V_R), which should be equal to or greater than the peak operating level defined at each circuit point of protection. It is the minimum guaranteed voltage protection, taking into consideration the complete operating temperature range of -65 to +175°C.

The **Peak Pulse Power** (P_p) defines the ability of the TransZorb to dissipate a rated peak power (refer to Figure A) under a

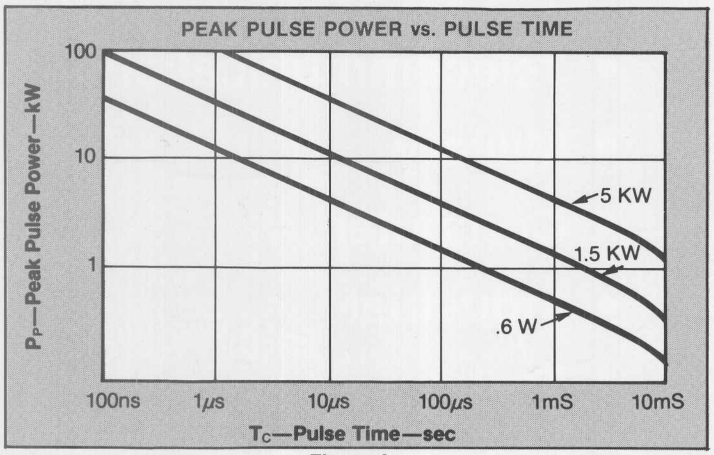
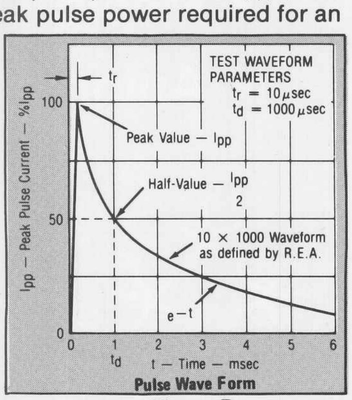


Figure A

defined transient condition (such as Figure B). It is the product of the clamping voltage (V_C) times the peak pulse current (I_p) (refer to Figure C). An initial level of peak pulse power required for an application can be estimated by knowing the placement of the TransZorb or assembly in the system. These levels of circuit protection insulation are described as *primary, secondary,* and *board level.*



Pulse Wave Form
Figure B

Primary protection installations are defined as a position in the circuit in which the protection element or network is exposed to the highest intensity, that is uncontrolled level, of induced transients. Severe transients are generated by lightning, power or line switching and power interruptions. For primary protection, a TransZorb alone may not be sufficient. It may require using another protection element ahead of the TransZorb® itself, Figures D and E (also refer to modular assembly brochure).

Secondary protection installations are defined as a position in the circuit in which the protection element is preceded by known series or line impedance. This impedance is a result of a circuit

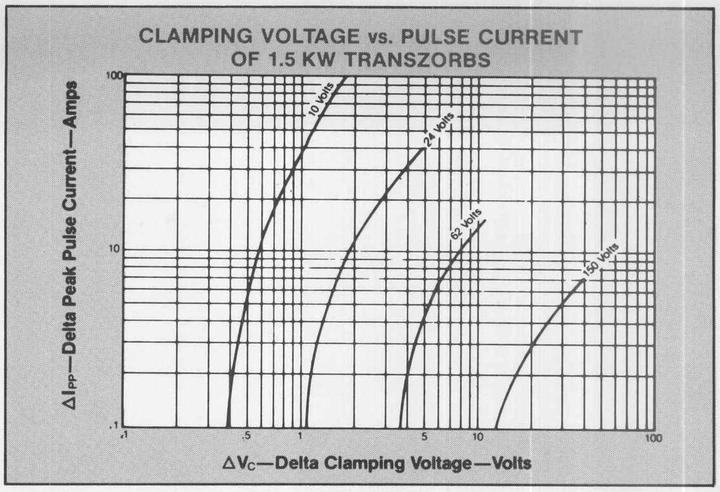


Figure C

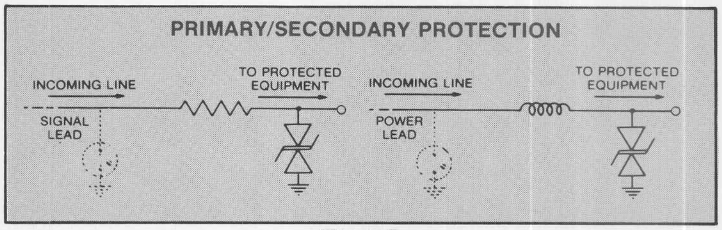


Figure D

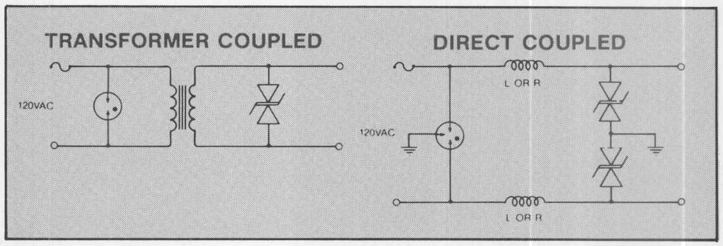


Figure E

design incorporating a resistor, inductor network, or a transformer or something of this nature, Figures F and G. For secondary applications, the 1N type series or the 1500 watt TransZorb will be sufficient in most applications. The P6KE or 500 watt type TransZorb can, however, be recommended for specific applications where the source impedance is high.

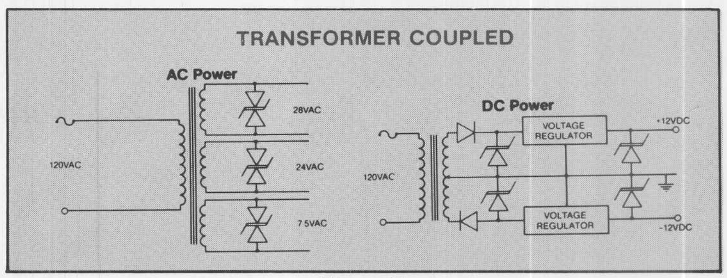


Figure F

Board level protection installations are defined for applications in which the protection element is placed on a circuit board, Figure H. This is for protection of sensitive circuits or components such as microprocessors, memory, signal lines, etc., from internally generated transients. In this kind of protection, we are looking at products such as the DIP, DQA/DQB or the Zorb, ESDA. In some applications, the SA series may be desired for

In case of a severe current overload or abnormal transient beyond the maximum ratings, the TransZorb will initially fail "short" thus tripping the systems' circuit breaker or fuse while protecting the entire circuit. However, if current is sustained in the shorted mode, the device may exhibit an open condition. If the shorted mode is a desirable designed characteristic, we recommend the TransZorb series types packaged in a DO-13 (metal) case.

throughout the industry in the specifications and *characterization* of transient voltage suppressors. The 10 x 1000 has been applied to solid state semiconductor devices such as the TransZorb®, whereas the 8 x 20 has been established for gas tubes and metal oxide varistors.

The third transient characteristic is the frequency of occurrence. This characteristic is for calculation of average power. This will determine whether one should use or recommend an axial lead device, or a stud mounted device for the repetitive pulses. If there are repetitive pulses or a certain duty cycle, one must take into consideration the average power dissipation of the TransZorb. Average power ratings that approach the steady state power rating, may require providing a package or housing to dissipate the heat.

There are some basic steps to consider in selecting a TransZorb® for an application. These are listed in Table 4. The *first* consideration is application or placement of the transient voltage protection within the system. If it can be determined, from the application information, whether it is a primary, secondary or board level protection installation, one can determine whether a single element or an assembly is required. If it's difficult to identify the installation level of protection, it is important to at least identify what requires protection, that is, equipment, system, circuits, or a specific component. From this information, it is possible to estimate the kind of power level for a protection element.

TRANSIENT VOLTAGE SUPPRESSOR CONSIDERATIONS
1. Application **2. Characteristics** **3. Design** **4. Cost vs. Protection Effectiveness**

Table 4

COMPUTER INTERFACE PROTECTION

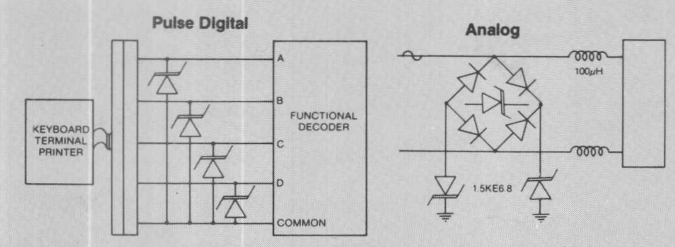


Figure L

If it is a primary installation, either a high power TransZorb is required or a lower power TransZorb in an assembly, which would employ the use of another protection element, such as, the gas tube, Figure D. In a secondary application, it is possible that one may be able to use a 1500 watt or a 600 watt unit (1.5KE or P6KE series type). For the board level installation, it is possible to use the smaller 500 watt device or even the new DQA DIP or Zorb ESDA, which can be placed on the circuit board to protect the sensitive components.

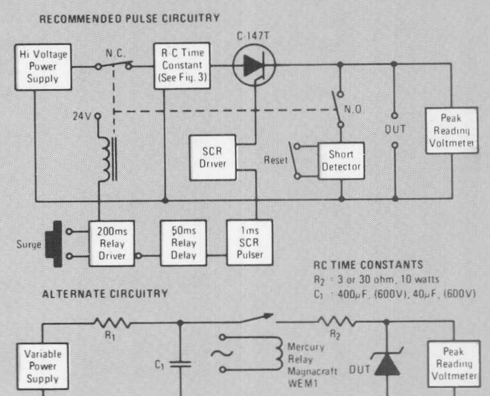
A *second* consideration for a TVS selection is the transient environment itself, which will lead us to the waveform *characteristics,* Figure K.

If it is possible to identify the transient environment or reference an industry standard transient it becomes easier to obtain information or estimate the actual characteristics of the transient, such as peak pulse current (I_{pp}). Amplitude, waveshape and frequency of occurrence are a consideration in the design and selection of a TransZorb®.

The *third* consideration is the design and selection of the device. Here one must be concerned about the peak pulse current, the operating voltage, and the peak pulse power capability of the TransZorb. This is where the rough accumulated data funnels down to the selection of the final device. The most important consideration is the actual system operating voltage which is equated to the reverse standoff voltage. Last, but not least, is the device selected designed for transient voltage protection.

Once the first three considerations have been analyzed, and a product selected and/or evaluated, the *fourth* consideration is up to the customer. This is his cost vs. protection effectiveness requirement. The question is actually the amount of insurance one is willing to pay to provide this protection. There are several power levels with the same voltage ratings to satisfy the user's insurance requirements. TransZorb selection would then be based upon the peak pulse power level to provide a specific level of reliability specified by the user.

Capacitor Discharge Circuit for Testing TransZorbs



RC TIME CONSTANTS: R_2 = 3 or 30 ohm, 10 watts; C_1 = 400μF, (600V); 40μF, (600V).

Note 2: The most significant electrical characteristic of transient suppressors is the surge handling capability. All TransZorbs are subjected 100% to the Maximum Peak Pulse Current (I_{pp}) as indicated in the electrical characteristic table and the clamping voltage is monitored. This test should be part of the customer's quality control incoming inspection procedure. Recommended commercial test equipment Keytek, Model 424 surge generator/monitor Keytek Inst. Co.

Figure M

TYPICAL CAPACITANCE vs. BREAKDOWN VOLTAGE

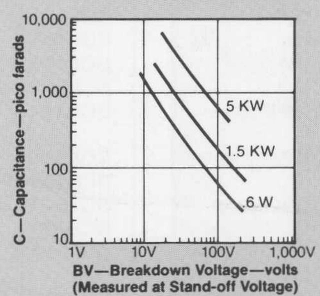


Figure N

DIGITAL CENTRAL OFFICE PROCESSING SYSTEM

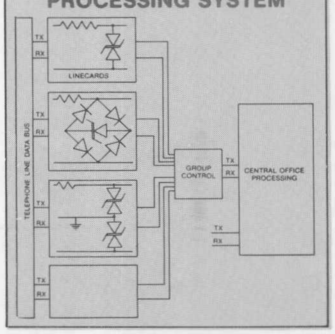


Figure O

For Further Information, Contact

TRANSZORB SELECTION GUIDE

PEAK PULSE POWER RANGE	LOW		MEDIUM						
PEAK PULSE POWER RATING	500W	600W	1000W	1200W	1500W				
APPLICATION	Computer, Consumer, Medical		Commercial		Telecommunication, Automotive, Military & Instrumentation				
POLARITY	Bipolar Types Available		Bipolar Types Available		Unipolar Only		Bipolar Only	Unipolar Only	Bipolar Avail…
SERIES (Case No.)	SA (Case 25)	P6KE (Case 7)	SCL (Case 1)	SCM (Case 1)	LCE† (Case 1)	1N56__* (DO-13)	1N60__** (DO-13)	1N62__ (Case 1)	1.5K… (Case…
STAND-OFF VOLTAGE (Note 1) V_R VOLTS	PART NUMBER								
5.0	SA5.0A		SCL5.0A	SCM5.0A					
6.0	SA6.0A	P6KE6.8A	SCL6.0A	SCM6.0A		1N5629A	1N6036A	1N6267A	1.5KE
6.5	SA6.5A	P6KE7.5A	SCL6.5A	SCM6.5A	LCE6.5A	1N5630A		1N6268A	1.5KE
7.0	SA7.0A	P6KE8.2A	SCL7.0A	SCM7.0A	LCE7.0A	1N5631A	1N6037A	1N6269A	1.5KE
7.5	SA7.5A		SCL7.5A	SCM7.5A	LCE7.5A		1N6038A		
8.0	SA8.0A	P6KE9.1A	SCL8.0A	SCM8.0A	LCE8.0A	1N5632A		1N6270A	1.5KE
8.5	SA8.5A	P6KE10A	SCL8.5A	SCM8.5A	LCE8.5A	1N5633A	1N6039A	1N6271A	1.5KE
9.0	SA9.0A	P6KE11A	SCL9.0A	SCM9.0A	LCE7.0A	1N5634A	1N6040A	1N6272A	1.5KE
10	SA10A	P6KE12A	SCL10A	SCM10A	LCE10A	1N5635A	1N6041A	1N6273A	1.5KE
11	SA11A	P6KE13A	SCL11A	SCM11A	LCE11A	1N5636A	1N6042A	1N6274A	1.5KE
12	SA12A		SCL12A	SCM12A	LCE12A		1N6043A		
13	SA13A	P6KE15A	SCL13A	SCM13A	LCE13A	1N5637A	1N6044A	1N6275A	1.5KE
14	SA14A	P6KE16A	SCL14A	SCM14A	LCE14A	1N5638A		1N6276A	1.5KE
15	SA15A		SCL15A	SCM15A	LCE15A	1N5639A	1N6045A	1N6277A	1.5KE
16	SA16A	P6KE18A	SCL16A	SCM16A	LCE16A				
17	SA17A	P6KE20A	SCL17A	SCM17A	LCE17A	1N5640A	1N6046A	1N6278A	1.5KE
18	SA18A	P6KE22A	SCL18A	SCM18A	LCE18A	1N5641A	1N6047A	1N6279A	1.5KE
20	SA20A	P6KE24A	SCL20A	SCM20A	LCE20A	1N5642A	1N6048A	1N6280A	1.5KE
22	SA22A		SCL22A	SCM22A	LCE22A	1N5643A	1N6049A	1N6281A	1.5KE
24	SA24A	P6KE27A	SCL24A	SCM24A	LCE24A		1N6050A		
26	SA26A	P6KE30A	SCL26A	SCM26A	LCE26A	1N5644A		1N6282A	1.5KE
28	SA28A	P6KE33A	SCL28A	SCM28A	LCE28A	1N5645A	1N6051A	1N6283A	1.5KE
30	SA30A	P6KE36A	SCL30A	SCM30A	LCE30A	1N5646A	1N6052A	1N6284A	1.5KE
33	SA33A	P6KE37A	SCL33A	SCM33A	LCE33A	1N5647A	1N6053A	1N6285A	1.5KE
36	SA36A	P6KE43A	SCL36A	SCM36A	LCE36A	1N5648A	1N6054A	1N6286A	1.5KE
40	SA40A	P6KE47A	SCL40A	SCM40A	LCE40A	1N5649A	1N6055A	1N6287A	1.5KE
43	SA43A	P6KE51A	SCL43A	SCM43A	LCE43A	1N5650A	1N6056A	1N6288A	1.5KE
45	SA45A		SCL45A	SCM45A	LCE45A				
48	SA48A	P6KE56A	SCL48A	SCM48A	LCE48A	1N5651A	1N6057A	1N6289A	1.5KE
51	SA51A		SCL51A	SCM51A	LCE51A				
54	SA54A	P6KE62A	SCL54A	SCM54A	LCE54A	1N5652A	1N6058A	1N6290A	1.5KE
58	SA58A	P6KE68A	SCL58A	SCM58A	LCE58A	1N5653A	1N6059A	1N6291A	1.5KE
60	SA60A		SCL60A	SCM60A	LCE60A				
64	SA64A	P6KE75A	SCL64A	SCM64A	LCE64A	1N5654A	1N6060A	1N6292A	1.5KE
70	SA70A	P6KE82A	SCL70A	SCM70A	LCE70A	1N5655A	1N6061A	1N6293A	1.5KE
75	SA75A		SCL75A	SCM75A	LCE75A		1N6062A		
78	SA78A	P6KE91A	SCL78A	SCM78A	LCE78A	1N5656A	1N6063A	1N6294A	1.5KE
85	SA85A	P6KE100A	SCL85A	SCM85A		1N5657A		1N6295A	1.5KE
90	SA90A	P6KE110A	SCL90A	SCM90A	LCE90A	1N5658A	1N6064A	1N6296A	1.5KE
100	SA100A	P6KE120A	SCL100A	SCM100A	LCE100A	1N5659A	1N6065A	1N6297A	1.5KE
110	SA110A	P6KE130A	SCL110A	SCM110A	LCE110A	1N5660A	1N6066A	1N6298A	1.5KE
120	SA120A		SCL120A	SCM120A	LCE120A	1N5661A		1N6299A	1.5KE
130	SA130A	P6KE150A	SCL130A	SCM130A	LCE130A	1N5662A	1N6067A	1N6300A	1.5KE
140		P6KE160A				1N5663A	1N6068A	1N6301A	1.5KE
150	SA150A	P6KE170A	SCL150A	SCM150A	LCE150A	1N5664A	1N6069A	1N6302A	1.5KE
160	SA160A	P6KE180A	SCL160A	SCM160A	LCE160A		• **1N6070A**		
170	SA170A	P6KE200A	SCL170A	SCM170A	LCE170A	1N5665A	• **1N6071A**	1N6303A	1.5KE
180		P6KE220A					• **1N6072A**		1.5KE
200									
220		P6KE250A							1.5KE
240									
260		P6KE300A							1.5KE
280									
300		P6KE350A							1.5KE
320									
340		P6KE400A							1.5KE

Note 1: A TransZorb is normally selected according to reverse "Stand-Off Voltage" (V_R) which should be equal to or greater than the DC or continuous peak operating voltag

*Available in JAN, JANTX & JANTXV MIL-S-19500/500, **507 & §434. • **UL Recognized** (UL) †Low Capacitance TransZorbs

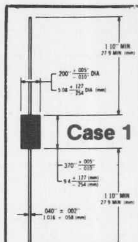
	HIGH	
	5000W	15000W
	Industrial, Motor Control #	
Types able	Unipolar Only	
E 1)	5KP (Case 23)	15KP (Case 24)
	5KP5.0A	
.8A	5KP6.0A	
7.5A	5KP6.5A	
.2A	5KP7.0A	
	5KP7.5A	
9.1A	5KP8.0A	
10A	5KP8.5A	
11A	5KP9.0A	
12A	5KP10A	
13A	5KP11A	
	5KP12A	
15A	5KP13A	
16A	5KP14A	
18A	5KP15A	
	5KP16A	
20A	5KP17A	15KP17A
22A	5KP18A	15KP18A
24A	5KP20A	15KP20A
27A	5KP22A	15KP22A
	5KP24A	15KP24A
30A	5KP26A	15KP26A
33A	5KP28A	15KP28A
36A	5KP30A	15KP30A
39A	5KP33A	15KP33A
43A	5KP36A	15KP36A
47A	5KP40A	15KP40A
51A	5KP43A	15KP43A
	5KP45A	15KP45A
56A	5KP48A	15KP48A
	5KP51A	15KP51A
62A	5KP54A	15KP54A
68A	5KP58A	15KP58A
	5KP60A	15KP60A
75A	5KP64A	15KP64A
82A	5KP70A	15KP70A
	5KP75A	15KP75A
91A	5KP78A	15KP78A
100A	5KP85A	15KP85A
110A	5KP90A	15KP90A
120A	5KP100A	15KP100A
130A	5KP110A	15KP110A
150A		15KP120A
160A		15KP130A
170A		
180A		15KP150A
		15KP160A
200A		15KP170A
220A		15KP180A
		15KP200A
250A		15KP220A
		15KP240A
300A		15KP260A
		15KP280A
350A		
400A		

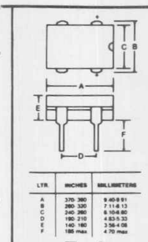
ge level. #Military Versions Available

ELECTRICAL CHARACTERISTICS @ 25° C

PART NUMBER	Stand-Off Voltage (V_R) (Note 1) Volts	Maximum Clamping Voltage @ I_{pp} V_C Volts	Maximum Peak Pulse Current I_{pp} (Note 2) (Fig. B) Amps	CASE NUMBER
§1N5555	30.5	47.5	32	DO-13
§1N5556	40.3	63.5	24	DO-13
§1N5557	49.0	78.5	19	DO-13
§1N5558	175.0	265.0	5.7	DO-13
*1N5907	5.0	7.6	30	DO-13
1N5908	5.0	7.6	30	1
704-15K36	31.5	51	300	2
704-15K36T	31.5	51	300	3
†DQA05	5.0	6.9	1	DQA
†DQA08	8.0	12.5	1	DQA
†DQA10	10	15.3	1	DQA
†DQA12	12	18.6	1	DQA
†DQA15	15	23.4	1	DQA
†DQA20	20	29.9	1	DQA
†DQA25	25	38.1	1	DQA
†DQA30	30	46.0	1	DQA
†DQA50	50	78.2	1	DQA
†DQB05	5.0	6.7	1	DQB
†DQB08	8.0	11.2	1	DQB
†DQB10	10	13.8	1	DQB
†DQB12	12	16.7	1	DQB
†DQB15	15	21.0	1	DQB
†DQB20	20	27.0	1	DQB
†DQB25	25	34.5	1	DQB
†DQB30	30	41.9	1	DQB
†DQB50	50	70.9	1	DQB
ESDA-5	5.0	6.7	1	Zorb
ESDA-8	8.0	11.2	1	Zorb
ESDA-10	10	13.8	1	Zorb
ESDA-12	12	16.7	1	Zorb
ESDA-15	15	21.0	1	Zorb
ESDA-20	20	27.0	1	Zorb
ESDA-25	25	34.5	1	Zorb
ESDA-30	30	41.9	1	Zorb
ESDA-50	50	70.9	1	Zorb
GMP-5	5.0	6.7	1	7
GMP-5A	5.0	6.7	1	7
GMP-5B	5.0	6.4	1	7
ICT-5	5.0	7.1	1	DO-13
ICT-8	8.0	11.3	1	DO-13
ICT-10	10	13.7	1	DO-13
ICT-12	12	16.1	1	DO-13
ICT-15	15	20.1	1	DO-13
ICT-18	18	24.2	1	DO-13
ICT-22	22	29.8	1	DO-13
ICT-36	36	50.6	1	DO-13
ICT-45	45	63.3	1	DO-13
ICTE-5	5.0	7.1	1	1
ICTE-8	8.0	11.3	1	1
ICTE-10	10	13.7	1	1
ICTE-12	12	16.1	1	1
ICTE-15	15	20.1	1	1
ICTE-18	18	24.2	1	1
ICTE-22	22	29.8	1	1
ICTE-36	36	50.6	1	1
ICTE-45	45	63.3	1	1
1N6356	5.0	7.1	1	DO-13
1N6357	8.0	11.3	1	DO-13
1N6358	10	13.7	1	DO-13
1N6359	12	16.1	1	DO-13
1N6360	15	20.1	1	DO-13
1N6361	18	24.2	1	DO-13
1N6362	22	29.8	1	DO-13
1N6363	36	50.6	1	DO-13
1N6364	45	63.3	1	DO-13
1N6373	5.0	7.1	1	1
1N6374	8.0	11.3	1	1
1N6375	10	13.7	1	1
1N6376	12	16.1	1	1
1N6377	15	20.1	1	1
1N6378	18	24.2	1	1
1N6379	22	29.8	1	1
1N6380	36	50.6	1	1
1N6381	45	63.3	1	1
PIP8.4	12	22	341	22
PIP24	34	67	112	22
PIP30	42.5	84	90	22
PIP60	85	167	90	22
•PIP120	170	319	47	22
PIP208	295	536	28	22
PIP250	354	652	23	22
PIP440	623	1138	13.2	22
PIP500	708	1292	11.6	22
•1.5KE200CA	171	274	5.5	1
•1.5KE220CA	185	328	4.6	1

†DQA/DQB series are 4 TransZorb dual-in-line package arrays. Optional voltages are available for specific applications.


Case 1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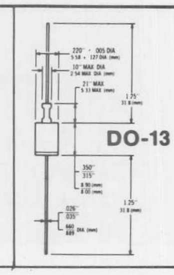
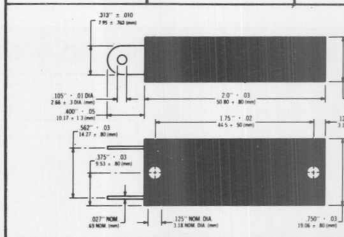

DO-13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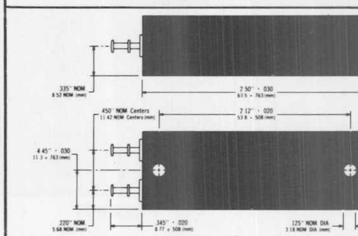
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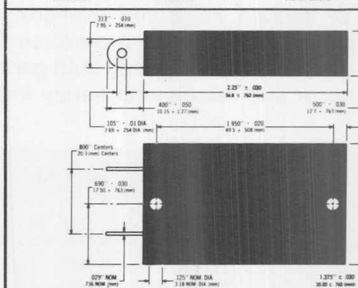
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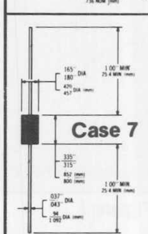
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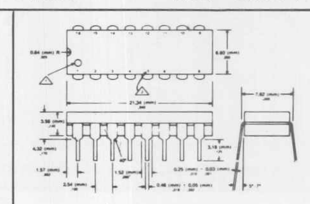
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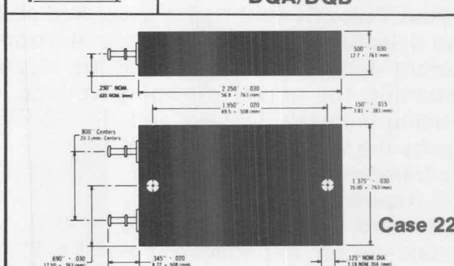
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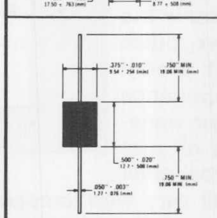
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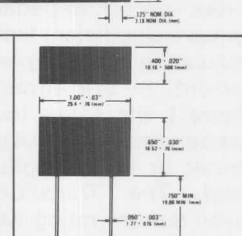
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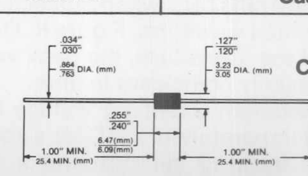

Case 25

Individual Data Sheets Available

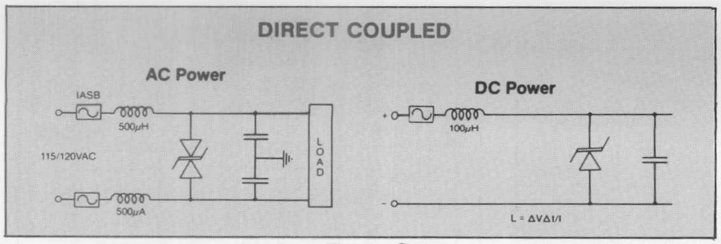

Figure G

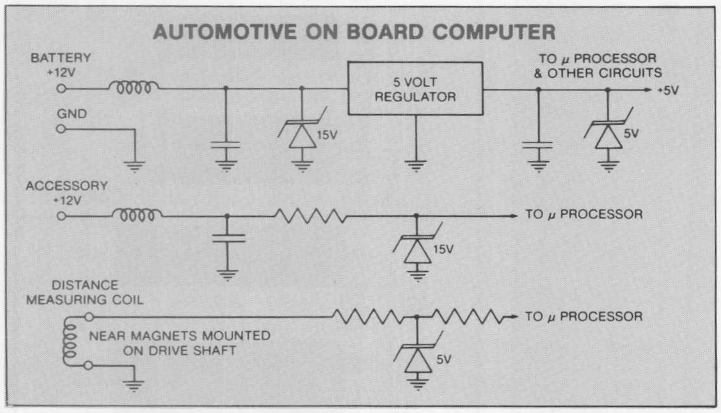

Figure H

board level protection. For board level protection, the component is placed right on the board for protection against such things as ESD, EMP or any electromagnetic field generator, such as motors or something of this nature which may induce voltage onto the line.

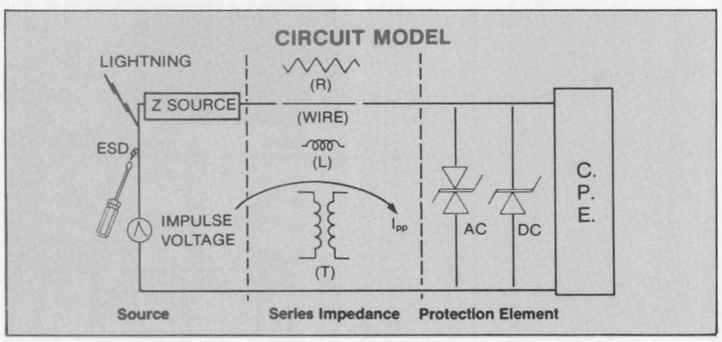

Figure I

Peak Pulse Current (I_{pp}) is a required parameter for the design and selection of a TransZorb® to withstand the instantaneous current density associated with the incident transient and for obtaining the actual clamping voltage. It is determined by dividing the peak transient voltage by the source impedance of the transient plus any series circuit impedance. For secondary and board level protection, the series circuit impedance becomes a significiant factor in the calculation of the peak pulse current. In the circuit model Figure I, the series impedance can be a resistor, inductor, transformer or even length of wire itself. The TransZorbs' peak pulse current rating will vary with temperature, see Figure J.

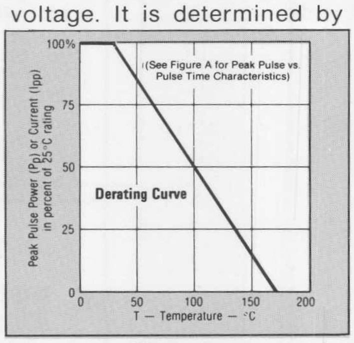

Figure J

The **Clamping Voltage** (V_C) is the peak voltage appearing across the TransZorb when subjected to the peak pulse current for a specified waveform, Figure K. Due to the thermal or reactive effects of the TransZorb, the peak voltage and peak current are not necessarily coincident in time.

The Maximum Clamping Voltage is the upper limit of protection at a temperature of 25° C for a specified impulse. When characterized by a 10 microsecond x 1000 microsecond impulse waveform, Figure B, the Maximum Clamping Voltage can be considered a maximum limit for shorter pulse widths. The 10 x 1000 impulse waveform has been proven, over the years, to be the best condition for characterization of the Maximum Clamping Voltage for all TransZorb device types.

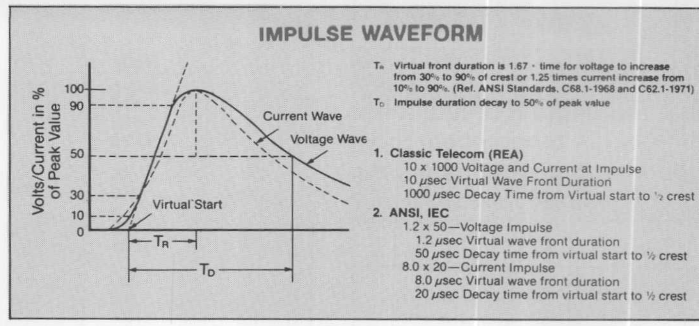

Figure K

Transients can or are generated from a number of different sources. However, for classification of these many sources and initial selection of a transient voltage suppressor, they can be defined into four categories (Table 1). Independent of the actual source of the transient, all have common characteristics. These common characteristics can be identified by three parameters: *Amplitude, Waveshape,* and *Frequency of Occurrence* (Table 3).

TRANSIENT SOURCES
1. Lightning 2. Inductive Switching 3. Nuclear EMP 4. Electrostatic Discharge

Table 1

DESIGN GUIDELINES FOR TRANSIENT VOLTAGE PROTECTION
1. Grounded Area 2. Shielded Area 3. Protection Element (system)

Table 2

TRANSIENT CHARACTERISTICS CONSIDERATION FOR PRODUCT DESIGN		
Amplitude	**Waveshape**	**Frequency of Occurrence**
1. Current (Amps) 2. Voltage (kilovolts) (source impedance, ohms)	1. Impulse (rise and fall time) 2. Damped sinusodial 3. Square wave	1. Repetition Rate 2. Duty Cycle

Table 3

These transient characteristics are important in the design and selection of a TransZorb®. For amplitude, it is the pulse current (I_p) that is of major concern. This current goes through the TransZorb and is the major parameter in the design of the transient voltage suppressor. If only the peak pulse voltage is known, some information about the source impedance is required to estimate the peak pulse current.

Energy is not one of the key transient characteristics. Energy within a transient is not completely dissipated by the transient voltage protector. The majority of the energy is dissipated by the source impedance or is, at least, reflected back to the source or line impedance.

The second characteristic is waveshape. The impulse waveform (Figure K) is the most predominant waveshape or envelope covering all transient categories. The initial impulse waveforms were originated for the telecommunications industry. This was originally known as the 10 x 1000 waveform. Ten is the risetime, which is related to ten microseconds, and the 1000 is the decay time, that is, a decay to the 50% point of peak value or, in this case, 1000 microseconds. The second is an 8 x 20 waveform which is for a current impulse, which is an 8 microsecond wavefront and a 20 microsecond decay to 50% of the peak value. The corresponding voltage waveform is 1.2 x 50 which is 1.2 microseconds risetime and 50 microseconds decay to 50% peak value. It is these two impulse waveforms that were originally established for the telecommunications industry and have been adopted